

## NEW TEST METHODS TO EVALUATE CHILD RESTRAINT SEATBACK STRENGTH

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### Abstract

New static and dynamic test methodologies were developed by Calspan Corporation to evaluate child restraint seatback strength. Four different types of child restraints were tested: 1) plastic with seatback folding feature, 2) tubular steel frame with plastic seat, 3) plastic shell, 4) plastic molded shell. The first seat type is currently being sold in Japan and has a unique seatback folding feature. This unique design allows the seatback to fold forward for convenience, ease of travel and storage. Seat types 2, 3, and 4 were each of different construction, currently sold in the U.S., and meet the U.S. dynamic test requirements for child restraints. The static tests were conducted by crushing the child restraint seatback with a large flat plate. The dynamic tests were performed on Calspan's HYGE sled using the standard, pivoting bench seat. Additional weight was added as ballast to the standard bench seatback to achieve enhanced dynamic loading on the child restraint seatback. Both of these test methods were able to provide data that could be used in evaluating the strength of child restraint seatbacks beyond the current standard. It was also found that the convenience feature of the folding child restraint did not appear to be detrimental to the child restraint safety.

### Introduction

Each year, between 500 and 700 infants and toddlers (under age 5) die in motor vehicle crashes. According to the National Highway Traffic Safety Administration (NHTSA), 571 children under age 5 died in motor vehicle crashes in 1992. For the majority of those deaths, approximately 70%, the infant or toddler was not in a child restraint or safety belt.

There are seven (7) major child restraint manufacturers and nearly 50 models of seats that are sold in the U.S. Clearly, there are plenty of child restraints to choose from, but, as the above statistics indicate, there is a reluctance to use them. It is possible that if the convenience of using a child restraint was improved, there would be increased use.

Manufacturers are continuously upgrading and improving upon the safety and convenience of child restraints. One manufacturer, Takata, has developed the Handy that has a unique seatback folding feature. Figure 1 shows the Takata Handy child restraint set-up for a HYGE dynamic test on the standard bench seat. Currently, this child restraint is sold only in Japan. Based on testing performed at Calspan, the seat appears to meet the current U.S. dynamic standards for child restraints.



Figure 1 Takata Handy child restraint

The Handy child restraint has a plastic shell structure and has a pivot point just above the vehicle seatbelt webbing path. This pivot point contains a hinge that allows the seatback to fold down onto the seating surface. The seatback folding feature allows for convenient storage and transportation of the child restraint. However, the folding feature raises some questions about the safety of the child restraint. For example, what is the strength of the hinge mechanism and how does the seatback strength compare to current child restraint seatback designs?

## Project Objective

Based on the safety concern of the folding child restraint design, the following project objective was established:

To develop test techniques that would evaluate the seatback strength of child restraints.

This main objective includes several secondary objectives. These were 1) finding the range of seatback strength for current child restraints, 2) finding the hinge strength of the folding child restraint, and 3) comparing the folding child restraint static and dynamic performance with the other types of child restraints.

## Child Restraint Types Tested

Four (4) different types of child restraints, each of different construction, were tested under this project. Three (3) of the child restraints are being sold in the U.S. and meet the current dynamic test standards (FMVSS 213). The child restraint types are listed below:

1. Plastic with seatback folding feature
2. Tubular steel frame with plastic seat
3. Plastic shell
4. Plastic molded shell

## Test Matrix

A series of baseline dynamic, static, and enhanced dynamic tests were performed during this project as in Table 1 below:

Table 1 Test Matrix

	Baseline Dynamic Test	Static Test	Enhanced Dynamic Test
Folding	3	3	3
Frame	-	3	3
Plastic	-	3	3
Plastic Mold	-	3	3

The baseline dynamic test was performed following Calspan's procedure for commercial child restraint testing. The baseline dynamic test results of the folding child restraint appears to indicate that the seat meets the current dynamic standard. Baseline test data for the other three (3) child restraints is available through the FMVSS 213 program. To evaluate repeatability, three (3) tests were performed on each child restraint under each test condition.

## Static Test

A schematic of the static test set-up used in the project is shown in Figure 2.

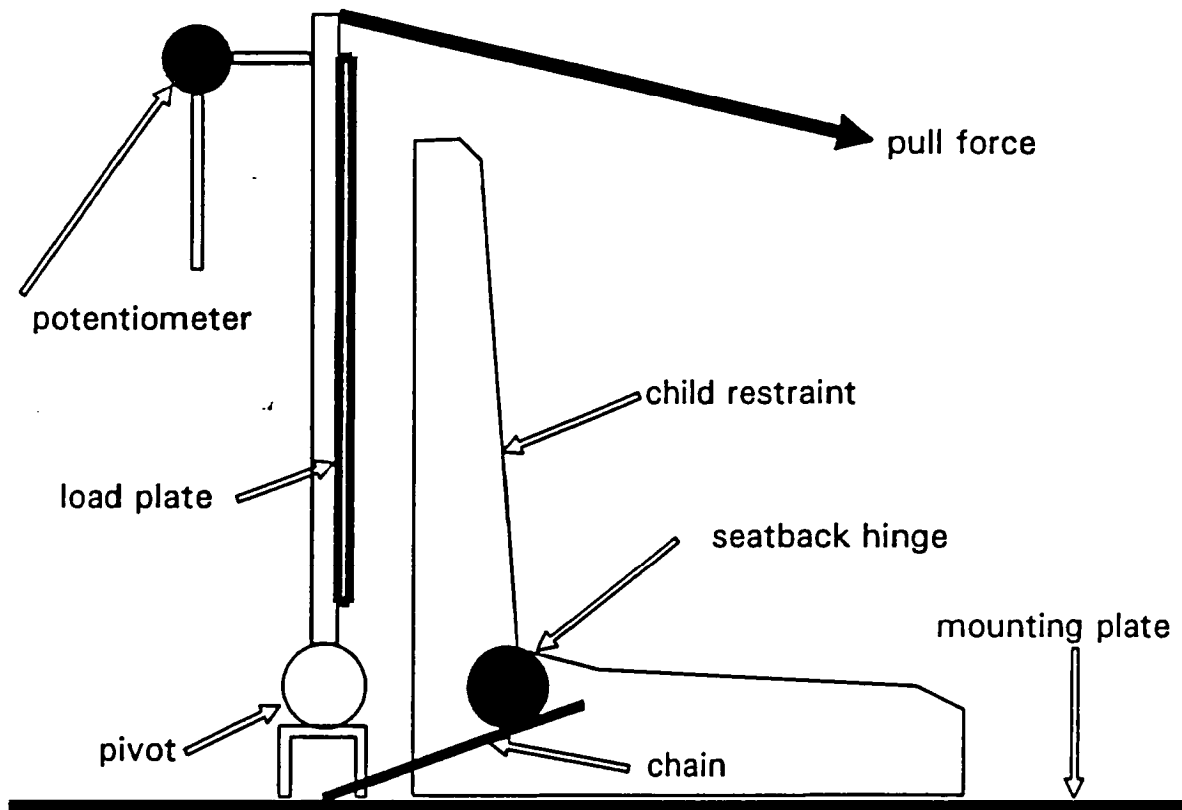


Figure 2 Schematic of static test set-up

Each child seat was placed on a flat steel mounting plate and the seats were secured using 1/4 inch steel chain through the normal seat belt webbing path. The chain was used to minimize the amount of belt stretch that may have occurred if webbing was used. The child restraint recline angle was set in its normal design position.

Attached to the mounting plate was a pivoting arm located behind the seat. The pivot point was at the same height as the folding seat hinge mechanism. This point was chosen to ensure that the all the load was transferred to the hinge mechanism and not into the seat base. Attached to the pivot arm was a steel load plate. The 1/2 inch thick load plate was 18 inches wide and 24 inches long. A potentiometer and counterweight were attached at the top of the pivoting arm to measure the load plate angle. A load was applied at the top of the pivot arm using a hydraulic cylinder and the pull force was measured using a load cell.

Figures 3 and 4 show photographs of the static pre-test set-up and the post-test condition of one of the folding child restraint tests. Figure 4 shows the load plate having been pulled forward and the child restraint seatback collapsed forward.

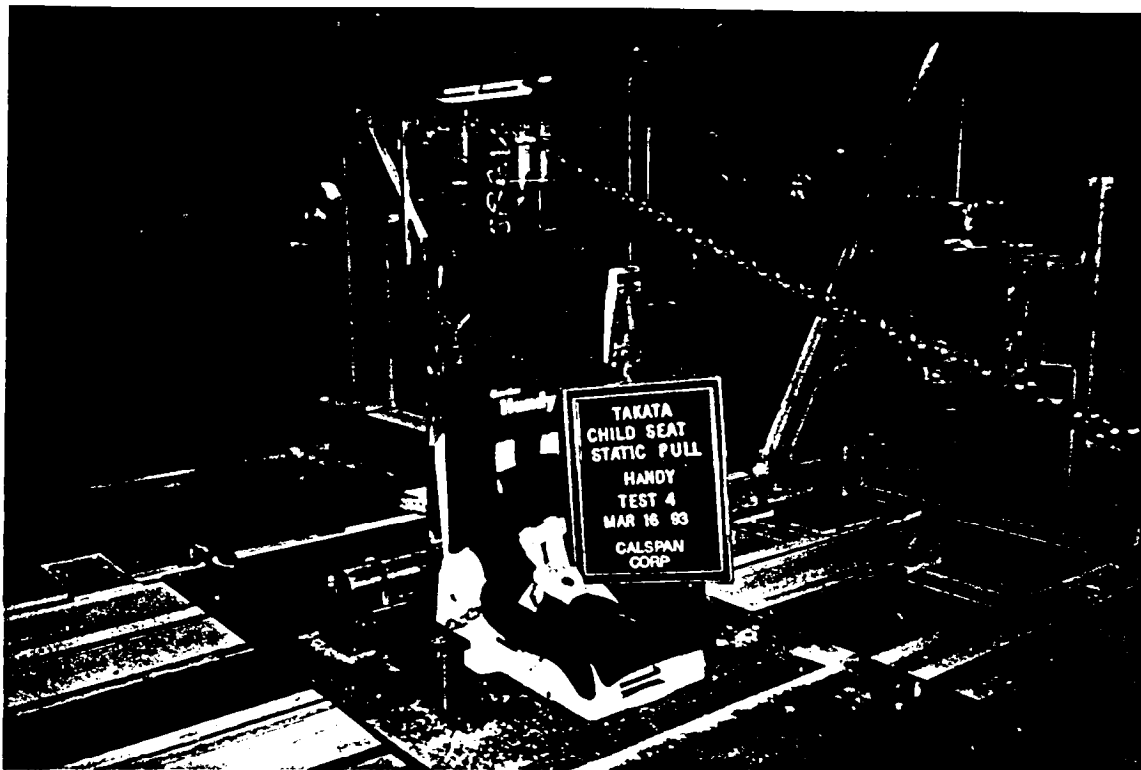


Figure 3 Static pre-test condition

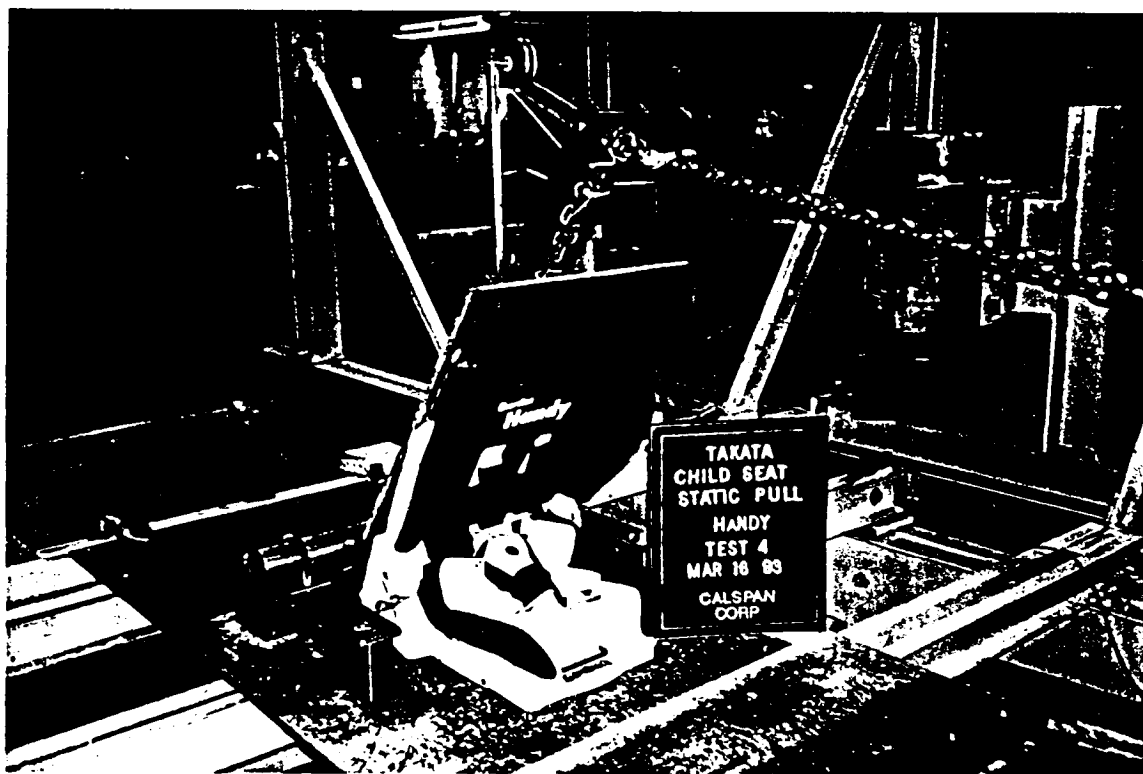


Figure 4 Static post-test condition

The pull force and load plate angle data from the static tests performed on each of the four (4) child restraints is presented in Figure 5 as an average moment-angle plot. The plot shows the seatback strength performance range of the four (4) different seat types tested. During a dynamic test (eg. FMVSS 213), the child restraint seatback angle change is very small, less than 10 degrees. The static moment-angle plot shows that up to about 10 degrees, the moment-angle relationship is similar for each of the four (4) seats. This indicates that the dynamic performance, in terms of seatback deflection, will likely be similar for the four (4) different seat types.

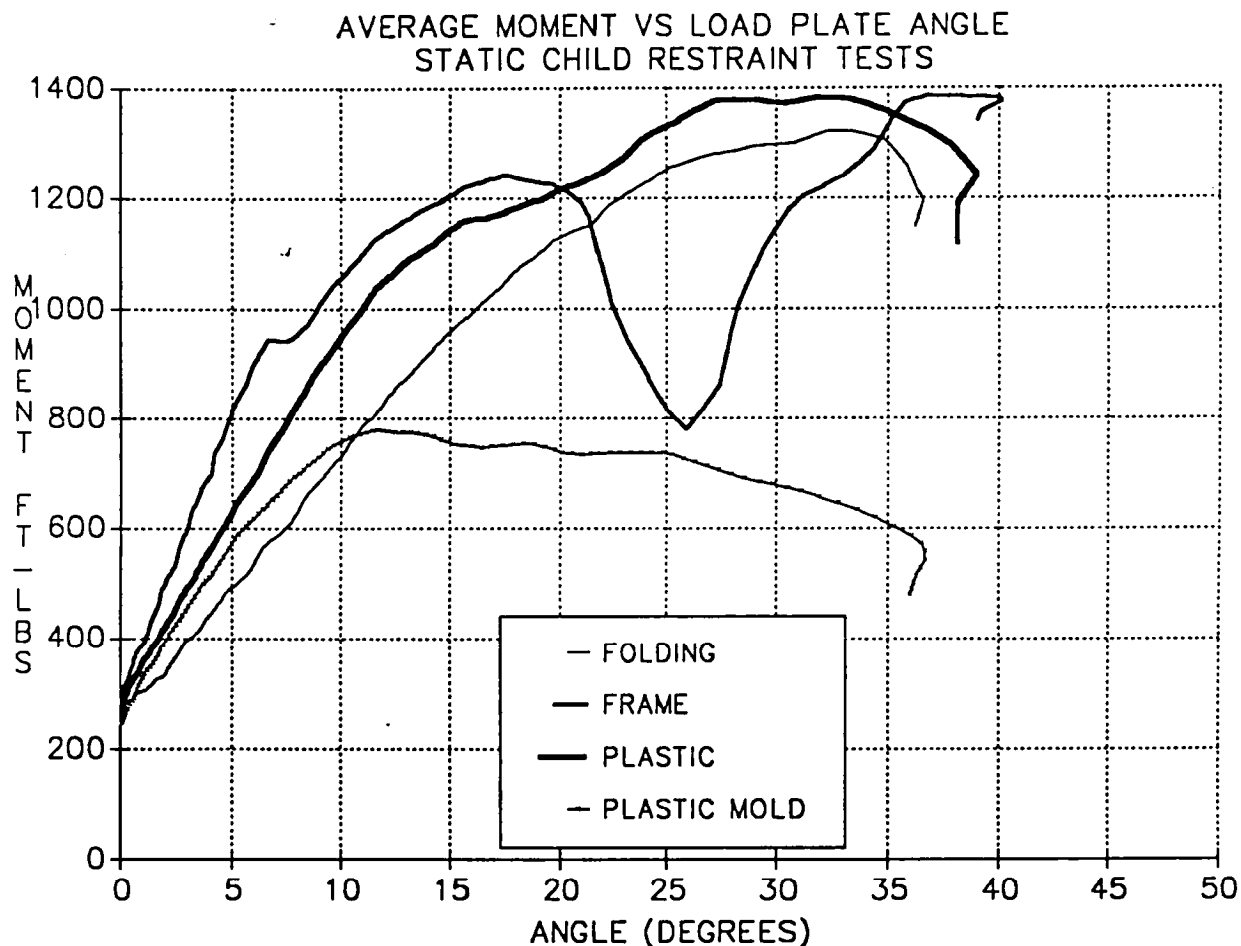


Figure 5 Static test moment-angle relationship

Three (3) of the child restraints, the folding, frame, and plastic, have similar performance response from the static test. This indicates that the hinge mechanism does not appear to inhibit the strength of the seatback and its response is similar to current child restraint designs. The dip in the moment/angle curve for the framed child restraint was caused by the chain slipping on the metal frame as the seatback deformed. After the slippage, the chain would again tighten-up and the load continued to increase. With some refinements in the test set-up and the seat fixture methodology, the resulting moment/angle curves could serve as design criteria for new seat development.

## Dynamic Test

A schematic of the dynamic test set-up used in the project is shown in Figure 6.

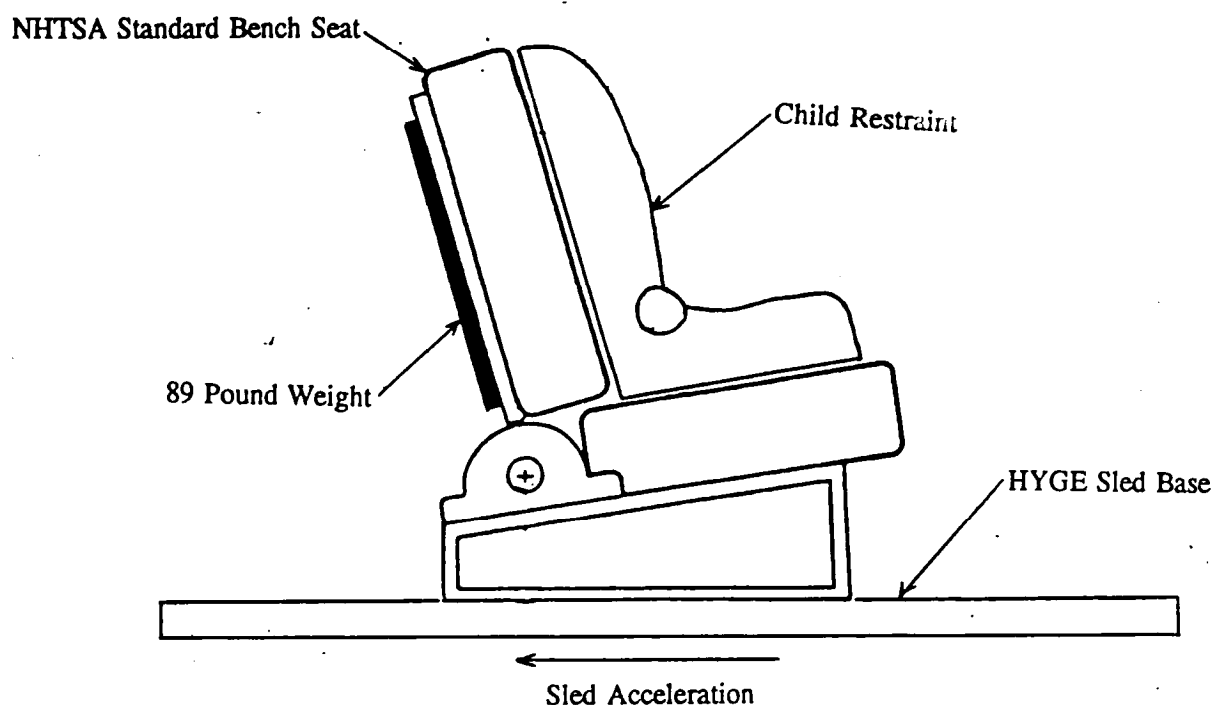


Figure 6 Schematic of dynamic test set-up

The dynamic tests, both baseline and enhanced, were performed on Calspan's HYGE sled test facility. The baseline dynamic test conditions followed Calspan's procedure for commercial infant and child restraint testing. The NHTSA standard bench seat was used mounted to the HYGE sled base. The standard bench seat accommodates forward bending of the seatback at the pivot point, through controlled bending of two 5/8" aluminum rods. The rods are located near the intersection of the seating surface and the seatback.

The child restraint was mounted in the center position of the standard bench seat assembly and was attached with polyester webbing. The vehicle lap belt webbing was placed through the normal belt path of each child restraint. A three year old P572 dummy was used, and the head x, y, z and chest x, y, z acceleration were measured. Post-test data processing was used to calculate the Head Injury Criteria (HIC) and 3 msec chest clip injury criteria.

On-board high speed cameras were placed on each side of the standard bench seat. High speed film analysis was used to measure knee and head excursion, and to measure the seatback angle change. The sled acceleration closely followed the FMVSS 213 corridor with a 22.5 g peak acceleration and an 80 msec duration. In terms of velocity, the acceleration pulse represented a 30 mph exposure.

The enhanced dynamic test conditions were the same as the baseline, however, additional weight was added to the seatback of the standard bench seat. The location of the additional weight is shown in Figure 6. The additional weight was added to the standard bench seatback to increase the dynamic force on the seatback of the child restraint and create a more severe test condition than the standard dynamic test. The enhanced dynamic test was developed to produce results that would better discriminate the seatback strength of child restraints than the standard dynamic test.

The basis for the 89 pounds of additional weight was to simulate an unrestrained 50<sup>th</sup> percentile male dummy striking the rear of the seatback. The specific weight was largely determined by the size of the steel plate that could be attached to the standard bench seatback. Figure 7 shows a photograph of the standard bench seat with the additional weight added to the seatback. Figures 8 and 9 show the enhanced dynamic pre- and post-test condition for one of the folding child restraints that was tested. Figure 9 shows significant forward deformation in the seatback of the standard bench seat. The large amount of forward motion in the seatback of the standard bench seat forces the child restraint into the seat cushion and pushes the child restraint seatback down toward the seating surface.

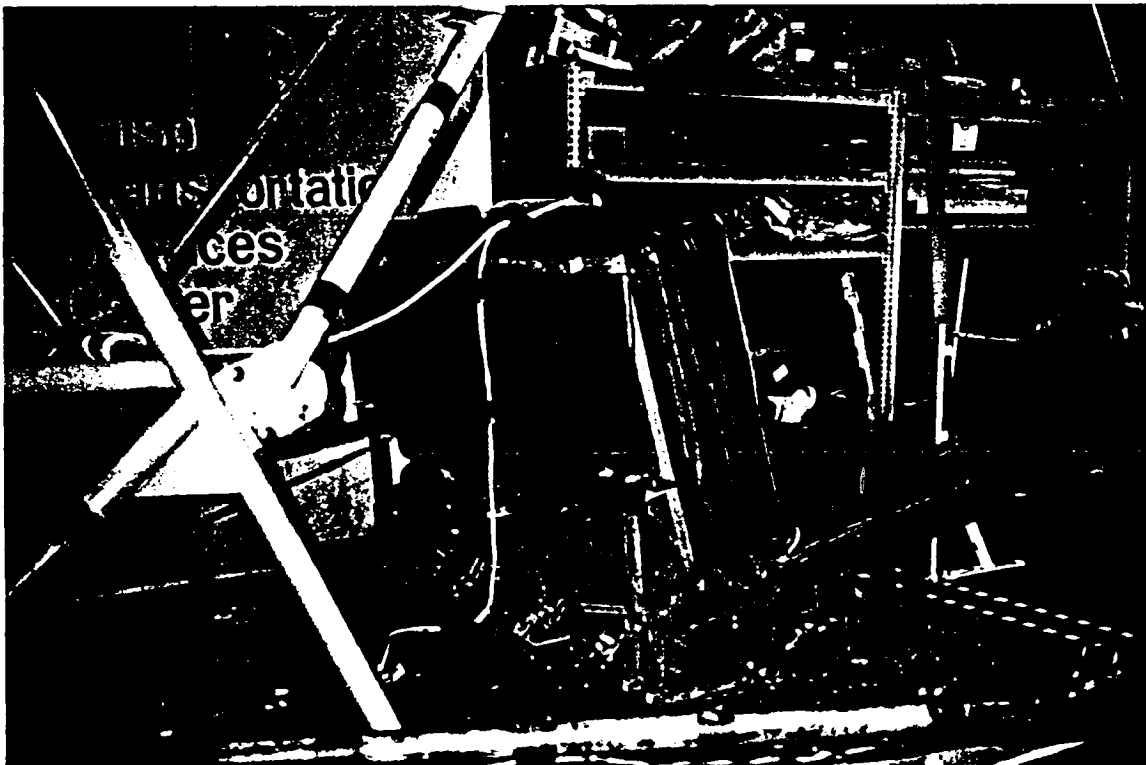


Figure 7 Standard bench seat with additional weight

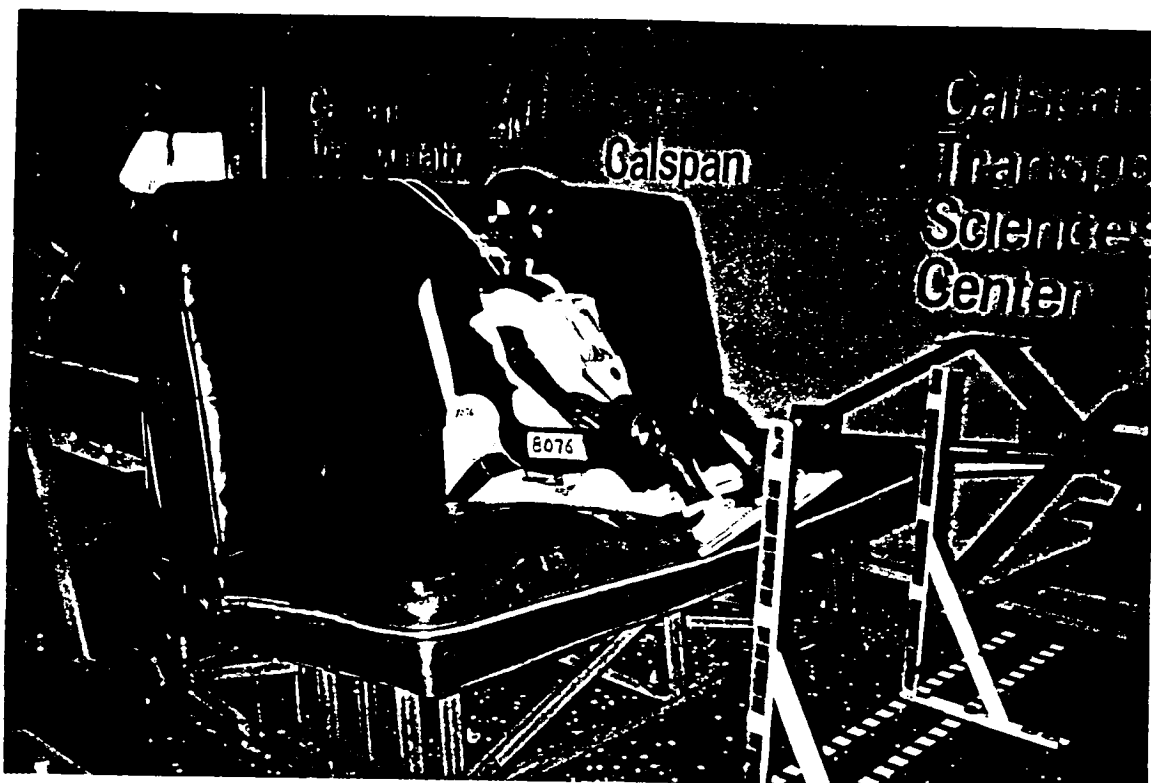


Figure 8 Pre-test condition for enhanced dynamic test



Figure 9 Post-test condition for enhanced dynamic test

Table 2 is a summary of the results for all the dynamic tests performed. The values given are the average of the three tests performed on each of the four (4) seat types.

Table 2 Dynamic test results summary

Child Restraint and Test Type	Child Restraint Average Values					
	HIC	3 msec chest clip Gs	Max Head Excursion (in.)	Max Knee Excursion (in.)	Child Restraint seatback angle change	Standard Bench Seatback angle change
Baseline Folding	691	43.0	31.7	32.6	6	21
Enhanced Test						
Folding	467	39.1	34.4	32.3	36	53
Frame	233	37.4	35.0	34.0	37	55
Plastic	432	40.0	33.3	31.9	9	51
Plastic Mold	238	48.8	33.2	32.4	55	53

The results from the dynamic baseline test on the folding child restraint show that it appears to meet the current dynamic requirements. The HIC, chest clip, head and knee excursions are below the current limits. A comparison between the baseline and enhanced test on the folding child restraint shows some performance change. Most notably, the head and chest injury criteria were lower and the head excursion increased for the enhanced test. The increased head excursion produced a lower head acceleration level, which reduced the HIC value.

The increased head excursion was caused by the increased seatback rotation of the standard bench seat. The additional weight on the standard bench seatback increased the load on the back of the child restraint. A significant increase in the angle change for both the child restraint seatback and the standard bench seatback occurred for the enhanced dynamic test.

The HIC and chest injury criteria for the enhanced dynamic tests performed on each of the four (4) child restraint types were below the standard dynamic limits. The average head excursion results from the enhanced dynamic tests were above the 32 inch limit. Again, the large amount of head excursion was caused by the large seatback rotation of the standard bench seat, giving the head more stroke. The average knee excursion results from the enhanced dynamic tests were below the 36 inch limit.

Figure 10 shows a summary of the dynamic test seatback angle change. It displays the range of both the child restraint and standard seatback angle changes. The child restraint values are shown by the shaded boxes and the standard bench seat values are shown by the lines. The averaged values are contained in Table 2.

## DYNAMIC TEST SEATBACK ANGLE CHANGE

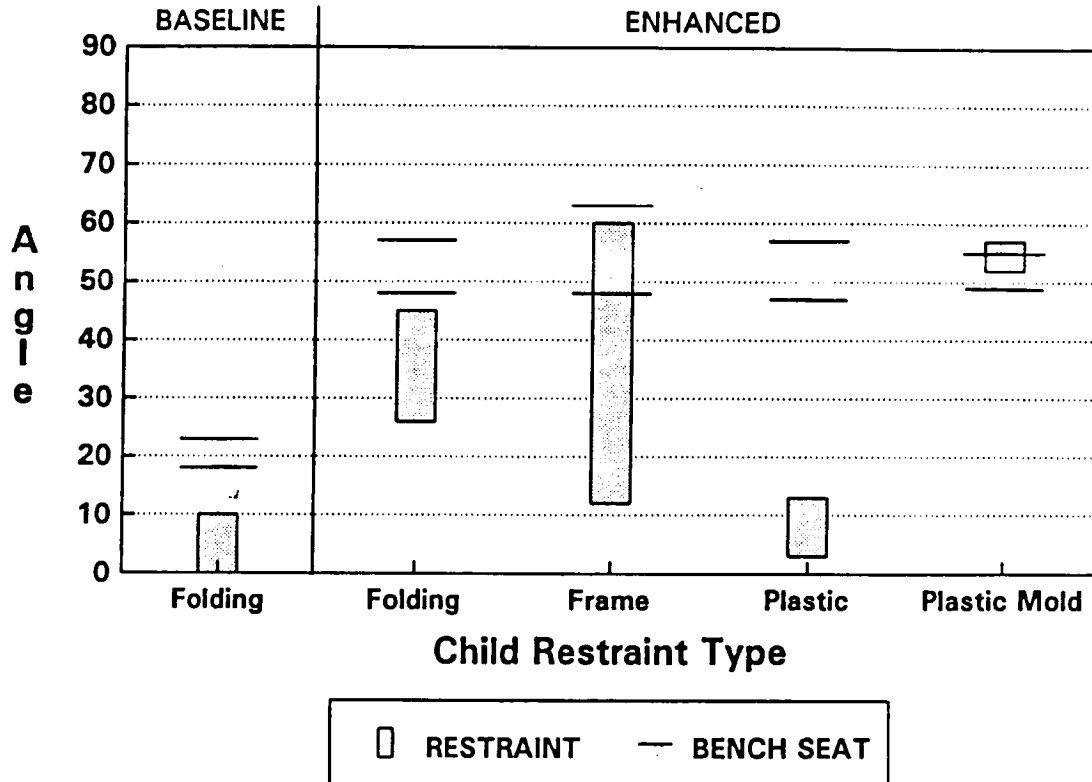


Figure 10 Dynamic test seatback angle change

The enhanced dynamic test results show that the standard bench had a consistent seatback angle change of 50 - 55 degrees for all 12 of the enhanced dynamic tests. During a baseline dynamic test the standard bench seatback rotates about 21 degrees. The child restraints; however, showed a much broader range of seatback angle change during the enhanced dynamic tests. The child restraint seat construction seemed to be the driving factor that determined the amount of seatback angle change.

The folding child restraint had a fairly consistent seatback angle change ranging from 26 to 45 degrees and an average value of 36 degrees. The results show that the seatback had sufficient strength to restrain the load from the standard seatback without fully collapsing.

The framed seat had an average seatback angle change of 37 degrees, however, the performance range was from 12 to 60 degrees. The framed seat type results shows the potential inconsistency of this type of seat construction.

The plastic seat type showed a small amount of seatback angle change in comparison to the other seat types and in comparison to the standard seatback angle change. The plastic seat construction was better able to withstand the force acting on its seatback from the enhanced dynamic test. The forward motion of the standard seat essentially "squeezed" the child restraint out between the seatback and seat cushion.

The plastic mold child restraint construction showed a weak performance in the enhanced dynamic tests. This seat type was not able to withstand the force generated by the standard bench seatback during the enhanced dynamic test. The child restraint seatback followed the rotation of the standard bench seatback. The result was that the child restraint seatback angle change was large (52- 57 degrees) and was nearly identical to the standard bench seatback angle change.

There appears to be a relationship between the static test results and the enhanced dynamic test seatback angle change. The plastic mold seat type had the lowest moment/angle relationship and it also had the largest seatback angle change during the enhanced dynamic test. The plastic seat type had the highest sustained moment-angle relationship and it had the lowest seatback angle change during the enhanced dynamic test. The folding and frame type child restraints had a moment-angle response and a seatback angle change that were between the limits of the plastic and plastic mold type child restraints.

## **Conclusions**

The objective, which was to develop test techniques that would evaluate the seatback strength of child restraints, was satisfied by the static and enhanced dynamic test configurations. These test techniques were used to establish the performance range and to better discriminate among various child restraint types.

The test methods provided seatback strength data beyond the current standard for child restraints. Modifications in the test set-ups should be evaluated. These may included the seat positioning, restraining method, and direction of load application for the static test. Also, seat positioning, ballast weight, and sled acceleration could be evaluated for the dynamic test set-up.

The moment-angle results from the static test could be used to establish a design range for new seat development. The dynamic test was able to evaluate the structural response and injury criteria for the child restraint. A response limit, in terms of structure and injury, needs to be established for the dynamic tests. Also, a more defined link between the static and dynamic test results needs to be established.

## **Acknowledgements**

This work was performed in cooperation with the Takata Corporation. Mr. Kenneth Naab and Mr. David Roberts of Calspan Corporation contributed to the project in the areas of test methodology, testing, analysis, and reporting.

## DISCUSSION

**PAPER:** New Test Methods to Evaluate Child Restraint Seat Back Strength

**SPEAKER:** Don Crane, Calspan Corporation

**QUESTION:** Linda Fulchasi, Ford Motor Company

I wanted to know if you've seen in the field this collapsed or crushed, broken-off seat back of these after market child seats?

**A:** No. We didn't try to establish any link to the real world. We wanted to try to just establish some performance of the child restraints, something above and beyond the standard. It has no link really to the real world as such. The hinge mechanism was a convenience for this full and child restraint. We need to see what it might do above and beyond the standard, sort of as a "do care" issue, but in the real world, we haven't tried to make a link.

**Q:** My concern is that we don't want to see a test procedure or something like this to lead to such a rigid structural seatback and, with the shoulder belts anchored on the seatbelt, there is not the give that you get in the flexible frame that exists today. You don't want the neck of the child to take all the load, if you have a very rigid seatback anchored with a shoulder belt. One more comment. It looks like in the test setup, I think I only saw the full Takata with a three year old in it. It looked like the head was above the after market child seatback. I haven't seen a three year old child head until now, maybe until it was just after the test, but it looked like the Takata seatback, the height of the seatback was a little low. It didn't expand to cover the head, the CG of the head.

**A:** As far as the relationship to what the criteria will be for, what is the criteria for 213 standard?

**Q:** I'm sure it meets it.

**A:** Yes. I can't really comment too much on that. Again, the seat's not being sold in the United States, just in Japan right now, but I'm not sure about the position of the seatback with respect to that.

**Q:** OK. Thank you.

**Q:** Ed Kennedy, Farmington Hills  
You said the 89 lbs. was to simulate an upper torso?

**A:** I was trying to simulate the fiftieth percentile without any legs, without the lower legs, pelvis, thorax, head.

**Q:** We use 75 lbs. for a steering column impact laboratory.

A: Yes. Again it was kind of arbitrary. We just tried to get a piece of steel basically that we would be able to attach to the back of the seatback.

Q: And what I was wondering is are you assuming that someone is going to hit the back of the seat?

A: It was some way to try to establish a method for trying to evaluate an enhanced test.

Q: To upgrade it you mean.

A: Yes, to try to upgrade it. It might in fact occur but it was just a way to try to establish the performance.

Q: The other thought I had is without adding to the seatback, increase an acceleration.

A: The pulse?

Q: The pulse, yes.

A: Yes. That could be done.

Q: And what you do that way is, you're not going to penalize a lower-weight seat compared to a higher weight because 89 lbs. on the back of, let's say a reduced weight seatback is going to be much more severe on that one than it would be on the heavier seat, so what I'm suggesting is a higher impact just without adding any weight to it.

A: Both of those were just to try to see what the performance of the folding would do in comparison to frame child restraint.

Q: OK. Thank you.